CIVILIZATION, ROLE OF SOILS

D Hillel, Columbia University, New York, NY, USA

© 2005, Elsevier Ltd. All Rights Reserved.

Human Management of the Soil

Manipulation and modification of the environment was a characteristic of many societies from their very inception. Long before the advent of earth-moving machines and toxic chemicals, even before the advent of agriculture, humans began to affect the land and its biota in ways that tended to destabilize natural ecosystems. In many of the ancient countries, where human exploitation of the land began early in history, we find disturbing examples of once-thriving regions reduced to desolation by human-induced degradation. Some of the early civilizations succeeded all too well at first, only to set the stage for their own eventual demise. The poor condition of the Fertile Crescent today is due not simply to changing climate or to the devastation caused by repeated wars, though both of these may well have had important effects. It is due in large part to the prolonged exploitation of this fragile environment by generations of forest cutters and burners, grazers, cultivators, and irrigators, all diligent and well-intentioned but destructive nonetheless.

An example of soil abuse on a large scale can be seen in the rainfed parts of the Mediterranean region, which has borne the brunt of human activity more intensively and for a longer period than any other region on earth. Visit the hills of Israel, Lebanon, Greece, Cyprus, Crete, Sicily, Tunisia, and southeastern Spain. There, rainfed farming and grazing were practiced for many centuries on sloping terrain, without consistent or fully effective soil conservation. The land has been denuded of its natural vegetative cover, and the original mantle of fertile soil has been raked off by the rains and carried down the valleys toward the sea. That may have been the reason why the Phoenicians, Greeks, Carthaginians, and Romans, each in turn, were compelled to venture away from their own country and to establish far-flung colonies in pursuit of new productive land. The end came for each of these empires when it had become so dependent on distant and unstable sources of supply that it could no longer maintain central control or ward off growing competition from other land-hungry nations.

Consider, for another example, the southern part of Mesopotamia. Aerial and satellite photographs of this area, now part of Iraq, reveal wide stretches of barren, salt-encrusted terrain. Long ago, these were fruitful fields and orchards, tended by enterprising irrigators whose very success inadvertently doomed their own land. The once-prosperous cities of Mesopotamia are now 'tells,' mute time capsules in which the material remnants of a civilization that lived and died there are entombed. Similarly ill-fated was the ancient civilization of the Indus Valley in present-day Pakistan.

There were, on the other hand, some societies that did better than others. The more successful ones were those who were able to develop modes of soil and land management that enabled them to thrive in the long run. Impressive evidence exists regarding the terrace-building farmers of eastern Asia and the Near East, as well as the wetlands-based societies of Meso-America and South America. Remarkably productive wetland management systems have survived in China and other parts of Southeast Asia. In contrast with the irrigation-based civilization of Mesopotamia, the similarly based civilization of Egypt sustained itself for more than five millennia – though it too (owing to its intensified management, impelled by its 20-fold increase of population in the last two centuries) is now beset with problems of waterlogging and salinity.

Historical Attitudes Toward the Soil

Early societies generally revered the earth and tended to deify it. The earth was held sacred as the embodiment of a great spirit, the creative power of the universe, manifest in all phenomena of nature. The earth spirit was believed to give shape to the features of the landscape and to regulate the seasons, the cycles of fertility, and the lives of animals and humans. Rocks, trees, mountains, springs, and caves were recognized as receptacles for this spirit.

The cult of the earth is perhaps the oldest and most universal element in all religions. The Australian aborigines and the African Bushmen, among the last to have maintained the preagricultural hunter-gatherer mode of life, have regarded the earth as the Great Provider, the source of all sustenance. So did – and still do – the native Americans. The ancient Egyptians represented the earth as the god Geb, who mated with the sky goddess Nut. The sexual roles were reversed in the culture of the ancient Canaanites, who worshiped the male Baal as the god of the sky, who provided the rain that fructified the earth goddess Ashera. To the ancient Greeks, the earth was Gaea, the maternal goddess who, impregnated by her son and consort Uranus

(god of the sky), became mother of the Titans and progenitor of all the many gods of the Greek pantheon.

In the Hebrew Bible, there are two very different accounts of creation and the role granted or assigned to humanity in the scheme of life on earth. In the first chapter of Genesis, we read that God (called 'Elohim') decided to "make man in our own image, and let them rule over the fish of the sea, and over all the earth, and over every creeping thing that creepeth upon the earth." And God blessed man and woman and said unto them: "Be fruitful, and multiply, and fill the earth, and conquer it... Here, I have given you every herb yielding seed and every tree with fruit... to you shall it be for food."

But the divine injunction to humanity is defined quite differently in the second chapter of Genesis. In this version, God (called 'Yahweh') "formed man out of the soil of the Earth and blew into his nostrils the breath of life, and man became a living soul." Then God planted a garden in Eden in the east and placed the man therein... to serve and preserve it." (Those words are this author's translation of the Hebrew words 'l'ovdah ul'shomrah' (Genesis 2:15), usually rendered "to dress it and keep it" (King James Version; or "to till it and keep it," Revised Standard Version.) Here, humanity is not given license to rule over the environment for self-gratification, but – quite the contrary – is charged with the responsibility to nurture and protect it.

Thus, latent in one of the main founts of Western Civilization we have two opposite perceptions of humanity's destiny. One is anthropocentric: humans are set above nature, to be its omnipotent masters. They are endowed with the power and the right to dominate all other creatures, toward whom they have no obligations. The other view is more modest. The human earthling is made of soil and is given a "living soul." There is no mention of being made "in the image of God." Humanity's appointment is not an ordination but an assignment, which is to serve as the custodians of God's garden.

Over the generations, unfortunately, it has generally been the arrogant and narcissistic view, implied in the first Biblical account, that has prevailed. It has repeatedly been cited and used as a religious justification or rationale for the unbridled and relentless exploitation of the environment. The imperative now is to accept and realize the long-ignored second view of our proper role in relation to nature.

Readers of the Bible in translation miss much of the imagery and evocative verbal associations in the original language. The indissoluble link between humanity and soil is manifest in the very name 'Adam,' derived from 'adamah,' a Hebrew noun of feminine gender meaning earth or soil. Adam's name encapsulates the notion that his existence is derived from the soil, to which he is tethered throughout life and to which he is fated to return at the end of his days. Likewise, the name assigned to Adam's mate, 'Hava,' rendered Eve in transliteration, literally means 'living.' In the words of the Bible, "Adam called his wife Hava because she was the mother of all living." Together, therefore, Adam and Eve signify "Soil and Life."

The ancient association of humanity with soil is echoed in the Latin name for man, 'homo,' derived from 'humus,' the stuff of the soil. This powerful metaphor suggests an early realization of a profound truth that has since been too often disregarded. Since the words 'humility' and 'humble' also derive from humus, it is rather ironic that we should have assigned our species so arrogant a name as *Homo sapiens sapiens* ('Wise Wise Man'). Perhaps a more appropriate and certainly more modest name would be *Homo sapiens curans*, with the last word denoting caring or caretaking, as in 'curator.'

Human Origins

Our species' birthplace was evidently in the continent of Africa, and its original habitat was probably the subtropical savannas that constitute the transitional areas of sparsely wooded grasslands lying between the zone of the humid and dense tropical forests and the zone of the semiarid steppes. We can infer the warm climate of our place of origin from the fact that we are naturally so scantily clad, or furless; and we can infer the open landscape from the way we are conditioned to walk, run, and gaze over long distances.

For at least 90% of its career, the human animal existed merely as one member of a community of numerous species who shared the same environment. Humans were adapted to subsist within the bounds defined by the natural ecosystem. By and large, our ancestors led a nomadic life, roaming in small bands, foraging wherever they could find food. They were gatherers, scavengers, and opportunistic hunters. Unlike their primate cousins who remained primarily vegetarian, humans diversified their diet to include the flesh of whichever animals they could find or catch, as well as a variety of plant products such as nuts, berries and other fruits, seeds, some succulent leaves, bulbs, tubers, and fleshy roots.

The story of how humans gradually ventured far from their original birthplace to range over a variety of climates and landscapes is a remarkable saga of audacity, ingenuity, perseverance, and adaptability. The mode of human adaptation was not entirely genetic or physical: there was not enough time for that. Rather, their adaptation was in large part behavioral.

Instead of relying on physical prowess, they had to use inventiveness to survive the elements and to compete successfully against stronger animals. The increase in brain size and manual dexterity, as well as the invention of various tools and stratagems, gradually enabled humans to overcome the constraints of their ancestry.

By 1 million years ago, hominids had become taller (approximately 1.5 m in height) and had acquired a larger brain. Some time later, the so-called *Homo erectus* learned to set and use fire, probably at first only for cooking and softening food. That achievement, along with the fashioning of stone tools, was a momentous innovation, celebrated in the Greek myth of Prometheus. Eventually, it had a great effect on the environment. Evidence has been found in southern and eastern Africa of repetitive occurrences of brush fires, whether purposeful or accidental, apparently set by humans nearly a million years ago. This early manifestation of pyrotechnology signifies the beginning of human manipulation of the earth's ecosystems. The use of fire became even more important when humans moved out of the tropics into colder climes, where bonfires and hearths were needed to warm their shelters in winter, as well as to cook their food.

The Paleolithic Transformation

At some point, humans began to use fires deliberately and systematically to flush out game and to modify the vegetation. The resultant suppression of woody plants and the fertilizing effect of ash encouraged the growth of herbaceous plants and improved their nutritional quality. This benefited foraging species and raised the carrying capacity for game animals. It also facilitated travel and hunting by humans. In time, the practice of clearing woodlands and shrublands by repeated firings also set the stage for the advent of agriculture.

As vegetation is affected by fire-setting hunters, so are soils. Following repeated fires and deforestation, soil erosion and landslides often result in the greatly increased transport of silt by streams, and in the deposit of that silt in river valleys and estuaries. The dating of fluvial sediments in river valleys in England, for example, suggests that they were the products of erosion caused by anthropogenic clearings in the originally closed deciduous forest during the Late Paleolithic period.

By approximately 40 000 years ago, modern humans, evidently indistinguishable from us today in physical features and in intelligence, had gained dominance. Clad in sewn garments made of animal skins, able to make and use a variety of implements and weapons, humans were able to range and settle in locations and climes far from their ancestral home. All the while they continued to evolve by natural selection, increasingly aided by cultural and technological development. They also contrived increasingly sophisticated methods of obtaining and storing foods, including the selective gathering, processing, and preservation of biological products, and eventually the domestication of plants and animals.

The described series of changes has been termed the Paleolithic (Early Stone Age) Transformation. It was marked by the development of adaptive mechanisms and modes of social organization suited to exploiting potentialities within the environment. Each modification of the environment entailed additional human responses, which in turn further modified the environment, so that a process of escalating, dual metamorphosis was instigated. Human intelligence and culture were both cause and effect in that fateful interplay. The peculiarly dynamic and progressive evolution of human ecology is the true history of our species.

The Agricultural Transformation

The gradual intensification of land use continued throughout the Paleolithic period, so that by its later stages nearly all the regions of human habitation had experienced some anthropomorphic modification of the floral and faunal communities. At some stage, humans began to delineate sections of the environment that they could control and manage to suit their special needs, and in which they could find secure shelters for habitation.

The process of intensification of land use can be seen as an adaptation to increasing population pressure. Several millennia of occupation by hunter-gatherers, even at a very low density and slow rate of population growth, filled up the terrain and decimated the natural forageable resources to the point where subsistence was difficult. The choice was then between migration and some form of intensification aimed at inducing the same area to yield a greater supply. The selective eradication of undesirable animal species and the encouragement of desirable ones led eventually to domestication and herding. Similarly, selective manipulation of plant communities involved suppressing some species and promoting the growth of others. The entire series of activities quite logically led to plant domestication and propagation, and to purposeful soil management aimed at creating favorable conditions for crop production – that is to say, these activities culminated in the development of agriculture and the agricultural way of life.

The Agricultural Transformation is very probably the most momentous turn in the progress of humankind, and many believe it to be the real beginning of civilization. Often called the Neolithic Revolution, this transformation apparently first took place in

the Near East, approximately 10 000 years ago, and was based on the successful domestication of suitable species of plants and animals. The ability to raise crops and livestock, while resulting in a larger and more secure supply of food, definitely required attachment to controllable sections of land and hence brought about the growth of permanent settlements of larger, coordinated communities. The economic and physical security so gained accelerated the process of population growth and necessitated further expansion and intensification of production. A self-reinforcing and self-perpetuating pattern thus developed, so the transition from the nomadic hunter-gatherer mode to the settled farming mode of life became in effect irreversible.

The Agricultural Transformation radically changed almost every aspect of human life. Food production and storage stimulated specialization of activities and greatly enhanced the division of labor that had already started in hunting-gathering societies. The larger permanent communities based on agriculture required new forms of organization, both social and economic. Domestication affected family structure and the roles and status of men, women, and children. With permanent facilities such as dwellings, storage bins, heavy tools, and agricultural fields came the concept of property. The inevitably uneven allocation of such property resulted in self-perpetuating class differences. Religious myths and rituals, as well as moral and behavioral standards, developed in accordance with the new economic and social constellation and the new relationship between human society and the environment.

The evolution of agriculture left a strong imprint on the land in many regions. The vegetation, animal populations, slopes, valleys, and soil cover of land units were radically altered. The processes of tillage and fallowing, of terracing, of irrigation and drainage have had considerable consequences for such processes as the erosion of slopes and the aggradation of valleys, as well as the formation of deltas in seas and lakes where silt from the land surface naturally comes to rest. Soil lost from deforested and subsequently cultivated slopes is unlikely to be regenerated unless the land is allowed to revert to its forest cover for many scores, perhaps even many hundreds, of years.

Soil Husbandry and Ceramics

An important factor in the evolution of agriculture in the Near East, as elsewhere, was the development of the tools of soil husbandry. Seeds scattered on the ground are often eaten by birds and rodents, or subject to desiccation, so their germination rate is likely to be very low and uneven. Given a limited seed stock, farmers would naturally do whatever they could to promote germination and seedling establishment. The best way to accomplish this is to insert the seeds to some shallow depth, under a protective layer of loosened soil, and to eradicate the weeds that might compete with the crop seedlings for water, nutrients, and light.

The simplest tool developed for the purpose was a paddle-shaped digging stick, by which a farmer could make holes for seeds. The use of this simple device was extremely slow and laborious, however, so at some point the digging stick was modified to form the more convenient spade, which could not only open the ground for seed insertion but also loosen and pulverize the soil and eradicate weeds more efficiently. In time, the spade developed a triangular blade, at first made of wood, but later made of stone, and eventually of metal. Such a spade, initially designed to be used by one person, was later modified so that it could be pulled by a rope so as to open a continuous slit, or furrow, into which the seeds could be sown. A second furrow could then be made alongside the first, to facilitate seed coverage. In some cases, the rows were widely enough separated to permit a person to walk between the rows, weeding the cultivated plot.

The human-pulled traction spade or 'ard' gradually metamorphosed into an animal-drawn plow. The first picture of such a plow, dating to 3000 BCE, was found in Mesopotamia, and numerous later pictures have been found both there and in Egypt, as well as in China. It was not long before these early plows were fitted with a seed funnel, so that the acts of plowing and sowing could be carried out simultaneously. The same ancient implement is still in use today in parts of the Near and Middle East.

While the development of the plow represented a huge advance in terms of convenience and efficiency of operation, it had an important side effect. As with many other innovations, the benefits were immediate, but the full range of consequences took several generations to play out, long after the new practice became entrenched. The major environmental impact was that plowing made the soil surface – now loosened, pulverized, and bared of weeds – much more vulnerable to accelerated erosion. In the history of civilization, contrary to the idealistic vision of the prophet Isaiah, the plowshare may well have been far more destructive than the sword.

As farming induced sedentary living in villages, there also developed an important new industry that depended directly on the soil – pottery, which began in the Near East at approximately 6000 BCE. The shaping and baking of clay to form hardened vessels for grain, for liquid storage and conveyance, and for cooking, represented the first transmutation of material by humans. Such an innovation could not

have been possible, owing to the fragility of the ceramic objects, during the nomadic hunting-gathering phase.

From Rainfed to Irrigated Farming

The Mediterranean-type climate of the Near East is at best semihumid, but more typically semiarid, with a rather high incidence of drought. Hence the practice of rainfed farming could not provide anything like total food security. The early farmers, who depended only on seasonal rainfall to water their crops, were always at the mercy of a capricious and highly unpredictable weather regime. The Hebrew Bible, for instance, is replete with references to the ever-present threat of drought and consequent famine. In time of need, therefore, it was only natural for farmers located near river courses to attempt to augment the water supply to crops by diverting water from the river. It was also reasonable to try to raise crops on riverine flood plains that were naturally inundated, and thereby irrigated, periodically.

Thus, many centuries after its advent, farming was extended from the relatively humid centers of its origin toward the extensive river valleys of the Tigris-Euphrates, the Nile, and the Indus. As the climate of these river valleys is quite arid, a new type of agriculture based primarily or even entirely on irrigation came into being. With a practically assured perennial water supply, an abundance of sunshine, a year-round growing season, deep and fertile soils, and relative security from the hazards of drought and erosion that beset rainfed farming, irrigated farming became a highly productive enterprise. However, behind its success lurked an insidious problem that could not have been foreseen initially: the problem of soil waterlogging and salination.

Silt and Salt in Ancient Mesopotamia

Ancient Mesopotamia owed its prominence to its agricultural productivity. The soils of this alluvial valley are deep and fertile, the topography is level, the climate is warm, and water is provided by the twin rivers Euphrates and Tigris. However, the diversion of river water onto the valley lands led to a series of interrelated problems.

The first problem was sedimentation. Early in history, the upland watersheds were deforested and overgrazed. The resulting erosion was conveyed by the rivers as suspended silt, which settled along the bottoms and sides of the rivers, thus raising their beds and banks above the adjacent plain. During periods of floods, the rivers overflowed their banks, inundated large tracts of land, and tended to change course abruptly. The silt also settled in channels and clogged up the irrigation works.

The second and more severe problem was salt. Seepage from the rivers, the irrigation channels, and the flood-irrigated fields caused the water table to rise throughout southern Mesopotamia. Because all irrigation waters contain some salts, and because crop roots normally exclude salts while extracting soil moisture, the salts tend to accumulate in the soil and groundwater. As the undrained water table rose, it took the salts back into the soil.

The farmers of ancient Mesopotamia attempted to cope with the process of salination by periodically fallowing their land, and by replacing the salt-sensitive wheat with relatively salt-tolerant barley. However, the process proceeded inexorably; so the ancient hydraulic civilizations of Sumer, Akkad, Babylonia, and Assyria each, in turn, rose and then declined, as the center of population and culture shifted over the centuries from the lower to the central to the upper parts of the Tigris-Euphrates valley.

The Sustainability of Egyptian Agriculture

In contrast to Mesopotamia, the civilization of Egypt thrived for several millennia in the same location. What explains the persistence of irrigated farming in Egypt in the face of its demise in southern Mesopotamia? The answer lies in the different soil and water regimes of the two lands. Neither clogging by silt nor poisoning by salt was as severe along the Nile as in the Tigris-Euphrates plain.

The silt of Egypt is brought by the Blue Nile from the volcanic highlands of Ethiopia, and it is mixed with the organic matter brought by the White Nile from its swampy sources. It was not so excessive as to choke the irrigation canals, yet was fertile enough to add nutrients to the fields and nourish their crops. Whereas in Mesopotamia the inundation usually comes in the spring, and summer evaporation tends to make the soil saline, the Nile rises in the late summer and crests in autumn. So in Egypt the inundation comes at a more favorable time: after the summer heat has killed the weeds and aerated the soil, just in time for the prewinter planting of grain.

The ancient Greek name for Egypt was 'Khemia,' from the word 'Khami' signifying black soil, which was what the Egyptians themselves called their land. So fabulously fertile was that dark deposit of the Nile (which contrasted vividly with the yellowish color of the nearby desert sand) that the Greeks considered it the mother lode of all material substances and apparently named the science of materials after it. That name has been transmuted into our term 'chemistry.'

The narrow floodplain of the Nile (except in the Delta) precluded the widespread rise of the water

table. Over most of its length, the Nile lies below the level of the adjacent land. When the river crested and flooded the land, the seepage naturally raised the water table. As the river receded and its water level dropped, it pulled the water table down after it. The all-important annual pulsation of the river and the associated fluctuation of the water table under a free-draining floodplain created an automatically repeating, self-flushing cycle by which the salts were leached from the irrigated land and carried away by the Nile itself.

The basis of Egypt's civilization was the nearly optimal combination of water, soil, nutrients, and organic matter, provided by the regular annual regime of the river, which was more dependable and timely than the relatively capricious floods of Mesopotamia. It enabled Egyptian farmers to produce a surplus that fed the artisans, scribes, priests, merchants, noblemen, and, above all, the Pharaohs, who used their power to order the building of monuments. Those monuments still stand today, less in testimony to the kings who ordered them than to the diligence and organization of a society of labor rooted in the soil.

See also: **Desertification**; **Erosion:** Water-Induced; **Irrigation:** Environmental Effects; **Salination Processes**

Further Reading

Carter VG and Hale T (1974) *Topsoil and Civilization*. Norman, OK: University of Oklahoma Press.

Hillel Daniel (1992) *Out of the Earth: Civilization and the Life of the Soil*. Berkeley, CA: University of California Press.

Hyams Edward (1976) *Soil and Civilization*. New York: Harper & Row.

Jacobsen Thorkild (1982) *Salinity and Irrigation in Antiquity*. Malibu, CA: Udena Publications.

Mitchell John (1975) *The Earth Spirit: Its Ways, Shrines, and Mysteries*. New York: Thames and Hudson.

Redman CL (1978) *The Rise of Civilization: From Early Farmers to Urban Society in the Ancient Near East*. San Francisco, CA: W. H. Freeman.

Rindos David (1984) *The Origins of Agriculture: An Evolutionary Perspective*. San Diego, CA: Academic Press.

Thirgood JV (1981) *Man and the Mediterranean Forest: A History of Resource Depletion*. New York: Academic Press.

Classification of Land Use *See* **Land-Use Classification**

CLASSIFICATION OF SOILS

R W Arnold, Formerly with USDA–Natural Resources Conservation Service, Washington, DC, USA

© 2005, Elsevier Ltd. All Rights Reserved.

A classification is an organized body of knowledge about something of interest. It is intended to show relationships among and between entities, and to help recall important properties of these entities. Three principles deal with the setup of a classification: 'purpose' states the reasons for wanting to organize soil knowledge; 'domain' specifies the universe of objects relevant to the purpose; and 'identity' defines and names the individual members of the domain. Four additional principles deal with the organization of a system: 'differentiation' specifies a protocol-guided hierarchical structure with categories and classes within categories; 'prioritization' is evident by sequencing categories and sequencing classes within categories; 'diagnostics,' whereby selected soil properties and features (diagnostics) are quantified, provide objectivity; and 'membership' is based on quantified class limits and described central tendencies. A final principle of certainty recognizes change as inevitable and the driving force for continual testing of a system.

Soils occur in most terrestrial environments and commonly have observable properties such as color and structure, arranged as layers; that is, soils have morphology. There are patterns of soil morphology throughout the world that are systematic enough to suggest causal relationships with other features of location.

In the late 1800s, 'pedology' originated from 'genetic soil science,' as termed by V.V. Dokuchaev, a Russian. He envisioned soils to be natural bodies of transformed materials at or near the interface of the lithosphere, biosphere, and atmosphere (**Figure 1**). Soils were recognized as cause-and-effect results of processes that were, and are, influenced by natural environmental factors and conditions: the factors of climate, biota, parent materials, and relief (landscape features) interact over time to produce soils. This was the most fundamental change in the concept of